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Article

Chronic Obstructive Pulmonary Disease in Sweden: An intersectional multilevel analysis of individual heterogeneity and discriminatory accuracy

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ABSTRACT

Socioeconomic, ethnic and gender disparities in Chronic Obstructive Pulmonary Disease (COPD) risk are well established but no studies have applied multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) within an intersectional framework to study this outcome. We study individuals at the first level of analysis and combinations of multiple social and demographic categorizations (i.e., intersectional strata) at the second level of analysis. Here we used MAIHDA to assess to what extent individual differences in the propensity of developing COPD are at the intersectional strata level. We also used MAIHDA to determine the degree of similarity in COPD incidence of individuals in the same intersectional stratum. This leads to an improved understanding of risk heterogeneity and of the social dynamics driving socioeconomic and demographic disparities in COPD incidence. Using data from 2,445,501 residents in Sweden aged 45–65, we constructed 96 intersectional strata combining categories of age, gender, income, education, civil- and migration status. The incidences of COPD ranged from 0.02% for young, native males with high income and high education who cohabited to 0.98% for older native females with low income and low education who lived alone. We calculated the intra-class correlation coefficient (ICC) that informs on the discriminatory accuracy of the categorizations. In a model that conflated additive and interaction effects, the ICC was good (20.0%). In contrast, in a model that measured only interaction effects, the ICC was poor (1.1%) suggesting that most of the observed differences in COPD incidence across strata are due to the main effects of the categories used to construct the intersectional matrix while only a minor share of the differences are attributable to intersectional interactions. We found conclusive interaction effects. The intersectional MAIHDA approach offers improved information to guide public health policies in COPD prevention, and such policies should adopt an intersectional perspective.

Introduction

Social epidemiological studies have long been criticized for the relative absence of explicit sociological theory (Krieger, 1994; Ng & Muntaner, 2014), and further integration of, and dialogue between, epidemiology and social theory has been advocated (Wemrell, Merlo, Mulinari & Hornborg, 2016). From this perspective, and following similar initiatives in the social sciences, several authors have argued for an integration of intersectionality theory within epidemiology and public health (Bauer, 2014; Bowleg, 2008; Evans, Williams, Onnela & Subramanian, 2017; Merlo, 2017; Merlo & Mulinari, 2015; Mulinari, Wemrell, Rönnerstrand, Subramanian & Merlo, 2017; Wemrell, Mulinari & Merlo, 2017b). The advantage of incorporating an intersectional framework in social epidemiology is that it goes beyond the unidimensional study of socioeconomic and demographic categorizations by considering the effect of belonging to specific strata simultaneously defined by multiple social, economic and demographic dimensions. Intersectionality theory stresses the possible existence of an interaction effect over and above the additive influence of the isolated dimensions (Bauer, 2014; Bowleg, 2008; Evans et al., 2017). In this study, we aim to apply an innovative methodological approach combining *multilevel analysis of individual heterogeneity and discriminatory accuracy* (MAIHDA) (Merlo, 2014, 2017) with an intersectional framework (Evans et al., 2017; Green, Evans & Subramanian, 2017;

Abbreviations: MAIHDA, Multilevel Analysis of Individual Heterogeneity and Discriminatory Accuracy; CI, Credible Interval; DA, Discriminatory Accuracy; ICC, Intra Class Correlation

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Wemrell, Mulinari & Merlo, 2017a). This approach may improve our understanding of both the heterogeneous distribution of risk in the population and the social dynamics driving socioeconomic and demographic disparities in health.

Chronic Obstructive Pulmonary Disease (COPD) constitutes a growing but underestimated population health challenge (GOLD, 2017) that by 2020 is predicted to become the third leading cause of death globally (Murray & Lopez, 1997). Smoking is considered the most important risk factor for COPD (GOLD, 2017). From a causal perspective, many individual level risk factors for COPD can be understood as downstream mediators of upstream social and economic determinants of health (Kaplan, 1999). While global initiatives are underway to investigate risk factors for COPD many, including smoking (Hiscock, Bauld, Amos, Fidler & Munafò, 2012), low birthweight (Brostrom, Akre, Katz-Salamon, Jaraj & Kaijser, 2013), exposure to biofuels (Po, FitzGerald & Carlsten, 2011) and hazardous particles in working environment (Boschetto et al., 2006) are differently distributed among social strata (GOLD, 2017). Whereas policy-documents may mention equity in health as an overarching aim (Schraufnagel et al., 2013; Socialstyrelsen, 2015b) the focus of clinical guidelines (GOLD, 2017) and public health strategies (Socialstyrelsen, 2015a) tend to downplay upstream interventions and little research is done on the social processes that drive disparities in COPD morbidity. Altogether, this may contribute to the image of COPD as a self-inflicted smoking related disease and increase feelings of guilt among COPD-patients (Lindqvist & Hallberg, 2010; Strang et al., 2014).

There is strong evidence that social and economic factors influence the risk of COPD (Gershon, Dolmage, Stephenson & Jackson, 2012; Schraufnagel et al., 2013; Stringhini *et al.* 2017). Most epidemiological studies consider one social categorization at a time (gender, class, civil- or migration status etc.) while the others are adjusted for. A limitation in the literature on socioeconomic disparities in health in general and on COPD risk in particular is the disregard for heterogeneity within socioeconomic categories (Gershon et al., 2012; Kanervisto et al., 2011; Miravitlles, Naberan, Cantoni & Azpeitia, 2011). Typically, studies on socioeconomic disparities in COPD-morbidity report odds ratios (ORs) (Chen, Breithaupt & Muhajarine, 2000; Marmot, Shipley, Brunner & Hemingway, 2001; Montnemery et al., 2001) or differences in prevalence (Eachus et al., 1996; Kainu et al., 2013), or other measurements of average risk differences, between social strata based on one factor at a time (e.g., income, education and occupation). This may inadvertently strengthen the belief in the effectiveness of selective interventions based on unidimensional categorizations. Indeed, some researchers suggest selective screening of COPD among people with low socioeconomic status (Dirven et al., 2013; Pleasants, Riley & Mannino, 2016). Yet it is known that measurements of average risk differences are insufficient to inform on the ability of an exposure category to discriminate individuals with an outcome from those without it. For instance, an OR that is usually considered high, for example OR = 10, can be associated with a low discriminatory accuracy (DA), due to heterogeneity within categories and overlap between categories (Merlo, Mulinari, Wemrell, Subramanian & Hedblad, 2017; Pepe, Janes, Longton, Leisenring & Newcomb, 2004). We have previously suggested that when reporting and interpreting risk factors, measures of average associations should be accompanied by analyses of heterogeneity using measures of DA, such as the area under the ROC curve or the intra-class correlation coefficient (ICC) obtained in multilevel regression modeling (Merlo, 2003, 2014, 2017; Merlo & Mulinari, 2015; Merlo, Chaix, Yang, Lynch & Råstam, 2005; Merlo et al., 2017).

As a further development of this line of research we (Merlo, 2014, 2017; Wemrell et al., 2017a) and other scholars (Evans et al., 2017; Jones, Johnston & Manley, 2016) have recently suggested the use of multilevel analysis of variance within an intersectional matrix framework. From the perspective of social epidemiology (Merlo, 2017), the intersectional MAIHDA approach can be used to evaluate the strength of intersectional strata for disease prediction. Among several conceptual and technical advantages (Evans et al., 2017; Jones et al., 2016; Merlo, 2017) the intersectional MAIHDA approach provides a feasible way of measuring multiple interactions and analysing groups of small size. By considering the social context (i.e., intersectional strata) as a higher level in the multilevel analysis, this approach also avoids the treatment of societal factors as individual level characteristics.

In the present study we apply MAIHDA to investigate an intersectional matrix that simultaneously considers different social power dimensions and therefore may improve our understanding of the socioeconomic, gendered and ethnically patterned distribution of COPD in society. Our investigation had three specific aims. First, we aimed to provide a detailed intersectional map of COPD risk in the population in order to evaluate to what extent intersectional categorizations help predict COPD at the individual level. Second, we sought to investigate whether potential differences in average incidence for COPD between intersectional strata depend on intersectional interaction or if the average risk differences are explained by the additive effects of the dimensions used to construct the intersectional matrix. Our third aim was to contribute to methodological development by applying intersectional MAIHDA in social epidemiology in general and the study of socioeconomic disparities in COPD incidence in particular.

Population and methods

Study population

The National Board of Health and Welfare, in coordination with Statistics Sweden, linked the register of the Total Swedish Population to other national databases such as the National Inpatient Register, the National Mortality Register, and the Longitudinal Integration Database for Health Insurance and Labor Market Studies (LISA), using the unique personal identification number given to each person residing in Sweden. In the data we analysed, the identification numbers were replaced with arbitrary numbers to safeguard the anonymity of the subjects. The Regional Ethics Review Board in southern Sweden as well as the data safety committees from the National Board of Health and Welfare and from Statistics Sweden approved the construction of the database used in this study.

In Fig. 1 we have visualized the selection of individuals included in the database. We restricted the population to individuals aged 45 years and older since COPD is a rare condition below that age (GOLD, 2017). To avoid the confounding effect of retirement we did not include individuals older than 65 years, which is the official age of retirement in Sweden. From 2,536,789 individuals aged 45 to 65 years and residing in Sweden at the baseline date of December, 31st 2010, we excluded 11,722 individuals who died during 2010 or 2011. We also excluded 54,161 individuals who had spent less than 5 years in Sweden to assure that the information on previous diagnosis of COPD was reliable. We also excluded 3643 individuals that emigrated during 2011 to make sure we could obtain information on incident COPD. Finally, since our study was concerned with incidence (i.e., new cases) of COPD, we excluded 21,762 individuals who received a COPD-diagnosis between 2006 and 2010. This rendered a final study sample of 2,445,501 individuals or 96% of the Swedish population in that age span.

Assessment of variables

The outcome variable was the presence or absence of a new diagnosis of COPD between January 1st, 2011 and December 31st, 2011. We defined COPD based on hospital diagnosis (visit to a hospital clinic or hospital discharge) using one of the following International Statistical Classification of Diseases and related Health Problems 10th revision (WHO, 2016) (ICD-10) codes: J40 (bronchitis, not specified as acute or chronic), J41 (simple and mucopurulent chronic bronchitis), J42 (unspecified chronic bronchitis), J43 (emphysema), or J44 (other chronic obstructive pulmonary disease).

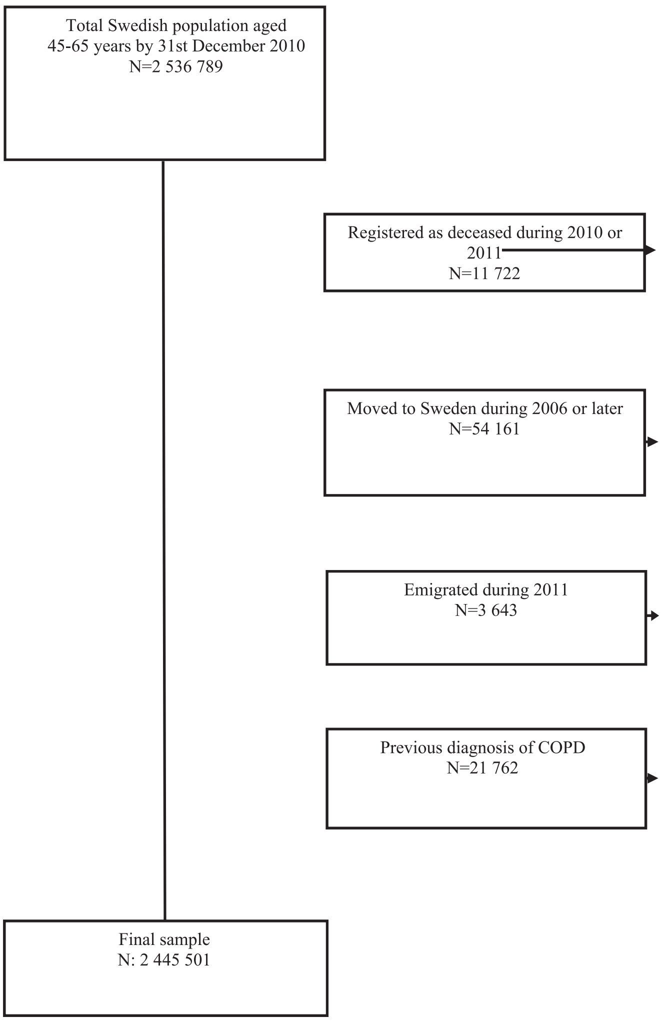

Fig. 1. Flow diagram showing the selection of the study population.

We categorized age into two categories (45–54 and 55–65). Gender was dichotomized as male or female according to legal status. We calculated household individualized disposable income by dividing the total disposable income of a family by the number of family members, taking into account the different consumption weights of adults and children, according to Statistics Sweden. Using the tertile values of the income distribution we divided the study population into three groups, termed high, medium and low income. We constructed two education categories based on whether individuals had any further education after high school or not, and these categories were also termed high and low. We computed a cohabitation variable by categorizing people that lived together as a married couple, in a registered partnership or with a common child as cohabiting and grouping all others into another category termed living alone. Finally, migration status was defined using information on country of birth from Statistics Sweden. We categorized people born outside Sweden as immigrants and individuals born in Sweden as natives.

Intersectional multilevel analysis of individual heterogeneity

We created a matrix with 96 intersectional strata based on combinations of age, gender, income, education, country of birth and cohabitation ($96 = 2 \times 2 \times 3 \times 3 \times 2 \times 2 \times 2$). The choice of these intersectional locations was restricted by the available information but it was to the largest degree possible informed by previous intersectional research (Bauer, 2014; Collins, 2002; Veenstra, 2013) and by what is known about associations between different social dimensions and mediators for COPD risk. Using this matrix, we performed an intersectional MAIHDA (Evans et al., 2017; Green et al., 2017; Merlo, 2017; Wemrell et al., 2017a) with individuals at the first level and the intersectional strata at the second level. We modelled COPD risk through three successive multilevel logistic regression models and estimated the predicted incidences and 95% credible intervals (CIs). To make the article as accessible as possible, we restrict the technical details of these models to Supplemental materials.

Model 1: Simple intersectional model

The first model is an *unadjusted,* random intercepts model (i.e., a variance components model) with individuals nested within intersectional strata. The purpose of this model was two-fold. First, we performed simple analysis of components of variance in order to calculate the ICC. This measure expresses the share of the total individual variance in the propensity for developing COPD that is at the intersectional stratum level. The higher the ICC, the greater the degree of similarity in COPD incidence within the strata and the greater the difference in incidence between the strata. Models with higher ICCs are therefore better at discriminating individuals that developed COPD from those that did not, compared to models with lower ICCs. In summary, the ICC evaluates the relevance of the intersectional strata for understanding individual risk heterogeneity. The ICC also informs on the DA of the intersectional categorization for distinguishing individuals with COPD from those without.

To calculate the ICC, we used the most popular version of the ICC derived from the latent response formulation of the model. This ICC was computed as:

$$\mathrm{ICC} = \frac{\sigma_u^2}{\sigma_u^2 + 3.29} \tag{1}$$

where σ_u^2 denotes the between-stratum variance in the propensity to receive a new COPD diagnosis and 3.29 denotes the within-stratum-between-individual variance constrined equal to the variance of the standard logistic distribution (Goldstein, Browne & Rasbash, 2002; Merlo et al., 2005). There is currently no official grading scale for interpreting the magnitude of the ICC within social epidemiology. However, in line with the terminology suggested for evaluation of psychometric test reliability (Cicchetti, 1994) we consider that a reasonable grading for social epidemiologic purposes could be (ICC as %): non-existent (0–1), poor (> 1 to ≤ 5), fair (> 5 to ≤ 10), good (> 10 to ≤ 20), very good (> 20 to ≤ 30), excellent (> 30).

The second purpose of this model was to calculate predicted incidence and the 95% CIs for every intersectional stratum. For doing so, and in order to use an additive scale, we transformed the predicted logit (log-odds) of receiving a new COPD diagnosis in stratum j obtained in the multilevel logistic regression into the probability of receiving a new COPD diagnosis in stratum j according the formula

$$\pi_j = \mathrm{logit}^{-1}(\beta_0 + u_j) \tag{2}$$

Model 2: Partially-adjusted intersectional model

The purpose of the *partially adjusted* model 2 was to quantify to what degree the different dimensions used to construct the intersectional strata contributed to the between stratum variance seen in the previous model. In six different versions we expanded model 1 by adjusting for one of these dimensions at a time (i.e., a different model for each dimension). Thereafter we calculated the Proportional Change in the between-stratum Variance (PCVs):

$$\mathrm{PCV} = \frac{\sigma_{u(1)}^2 - \sigma_{u(2)}^2}{\sigma_{u(1)}^2} \tag{3}$$

where $\sigma_{u(1)}^2$ and $\sigma_{u(2)}^2$ denote the between-stratum variance from models 1 and 2 respectively. PCVs are typically multiplied by 100 and reported as percentages.

Model 3: Intersectional interaction model

The ICC of model 1 represents the ceiling of the explanatory power of the intersectional strata and encompasses both additive and potential interactive effects of the variables that define the strata. Model 3 expands model 1 by simultaneously including as fixed main effects all the variables used to construct the intersectional strata. In the absence of stratum specific interactions, the inclusion of the main effects would completely explain between stratum variance and all 96 stratum random effects would equal zero. If this is not the case, the stratum residuals represent the excess risk due to interaction and the stratum variance and corresponding ICC of model 3 represents that part of the original model 1 stratum variance that is due to intersectional interaction effects, at least in relation to the set of variables included. This model also yields mutually adjusted unidimensional ORs representing the main effects of age, gender, income, education, civil status and migration status, respectively.

Model 3 was used to calculate *total predicted incidences* (main effects and interactive effects) and *predicted incidences based on the main effects* only. By subtracting the incidence attributable to main effects from the total incidence we isolated the incidence attributable to interaction in each intersectional stratum. We also calculated their 95% CIs. A positive interaction effect means that individuals in that intersectional stratum have a *higher* incidence than expected based on the simple addition of the risks conveyed by the categories that constitute the intersectional stratum, while a negative interaction means a *lower* incidence than expected. For further details, see the *statistical details*.

Software

The models were fitted using Markov chain Monte Carlo (MCMC) methods as implemented in MLwiN version 3.01 (Browne, 2017; Charlton, Rasbash, Browne, Healy & Cameron, 2017). We called MLwiN from within Stata version 14.1 using the runmlwin command (Leckie & Charlton, 2013).

Results

Overall, 0.22% (5419/2,445,501) of the study population developed COPD in 2011. As expected, we observed (Table 1, model 3) that, compared to men, women had a higher incidence of COPD. The same was true for high compared to low age, low and medium compared to high income, low compared to high education, as well as for people living alone and immigrants compared to people cohabiting and natives, respectively.

Table 2 (for full version see Table A1 Appendix) presents the number of individuals, number of new cases of COPD, and the model 1 total predicted incidences (main effects and interaction effects). The stratum with the highest predicted incidence of COPD comprised older native females with low income and low education who lived alone (0.98%, 95%CI: 0.89%–1.08%). It was followed by the strata including older immigrant females, with low income and low education who lived alone (0.87%, 95%CI: 0.72%–1.05%) and older immigrant males with low income and low education who lived alone (0.82%, 95%CI: 0.66%–1.00%).

At the other side of the spectrum, the strata with lowest predicted incidences included young native males with high income and high education who cohabited (0.02%, 95%CI: 0.01%–0.04%). It was followed by young native males with medium income and high education who cohabited (0.03% 95%CI:0.02%–0.04%) and by young native males with low income and high education who cohabited (0.03%, 95%CI: 0.02%–0.05%).

The ICC of model 1 (see Table 1) was good (i.e., 20.0%), which means that a substantial share of the total individual differences in the propensity of suffering from COPD was at the intersectional strata level. In the age-adjusted model (model 2) the ICC fell to 10.8%, which demonstrates that half of the clustering of COPD incidence observed in model 1 was attributable to the age of the individuals. In similar analyses with adjustment for one dimension at a time (not shown in tables) the ICC changed to 17.7%, 17.8%, 18.2%, 20.0 and 20.4% when we adjusted for civil status, education, income, migration status and gender respectively. Thus, age was by far the most important single factor in explaining variation in the propensity of developing COPD between strata. In the intersectional interaction model (model 3) the ICC dropped to 1.1%, which suggests that additive rather than interactive effects of age, gender, income, education, civil status and country of birth, explain most of the differences in COPD incidence across intersectional strata.

Fig. 2 demonstrates the heterogeneity between intersectional strata in predicted COPD incidence based on model 1 and thus conflating main and interaction effects of the six social dimensions. Fig. 3 demonstrates the small changes in predicted incidence in model 3 when comparing predictions based on the total effects with predictions based on main effects only. The difference between these predictions represent the interaction effects. The isolated interaction effects are visualized in Fig. 4. Most strata have interaction effects that cannot be statistically distinguished from 0. Three strata, however, have positive interactions and 95% CIs excluding 0: young native women with low income and low education who cohabited (interaction effect 0.13 95%CI 0.07–0.20), young native males with low income, low education who lived alone (interaction effect 0.08 95%CI 0.03–0.13) and young native women with medium income and low education who lived alone (interaction effect 0.06 95%CI 0.01–0.11). This finding is consistent with the poor ICC observed in model 3 and illustrates that the interaction effects are small.

Discussion

Our study advances social epidemiological research by incorporating MAIHDA (Merlo, 2014) within an intersectionality framework (Merlo, 2017). By doing so, we go beyond unidimensional measures of socioeconomic position to improve our understanding of risk heterogeneity and social dynamics driving disparities in COPD incidence in the society. While MAIHDA has mainly been applied for investigating geographical (Merlo, 2003; Merlo, Wagner, Ghith & Leckie, 2016) and institutional effects (Ghith, Wagner, Frolich & Merlo, 2016; Ohlsson, Librero, Sundquist, Sundquist & Merlo, 2011) on individual outcomes, pioneers scholars (Evans et al., 2017; Green et al., 2017) have applied this methodology for analysing an intersectional matrix of interlocking social dimensions. This innovative approach represents, we think, a major step forward in the study of socioeconomic and demographic disparities in health in general, including COPD incidence.

Socioeconomic distribution of COPD incidence and intersectional interaction

We found that intersectional strata defined by combinations of age, gender, income, education, civil status and country of birth provided good information for classifying individuals according to their COPD incidence in Sweden, with an ICC of 20.0%. The intersectional strata effect was mostly additive, and half of it due to the age differences between the strata. About 1.1% of the individual differences in COPD risk were due to the interaction effect between the variables defining the intersectional strata.

The intersectional multilevel approach allowed us to map socioeconomic differences in health in the population and, thereby, identify specific strata with an overtly increased COPD incidence (e.g., older native females with low income and low education who lived alone).

Table 1
Results from the intersectional multilevel analysis of individual heterogeneity in Chronic Obstructive Pulmonary Disease (COPD) risk, for people aged 45–65 residing in Sweden 2010, according to demographic and socioeconomic groupings used to construct intersectional strata. Model 1 (simple intersectional) is a random intercepts model with individuals nested in intersectional strata. Model 2 (age adjusted) is partially adjusted for and model 3 (intersectional interaction) is adjusted for all the main variables used to define the intersectional strata. In this table we present only measures of variance and of association (ORs and 95% CIs) between the main individual variables and COPD risk. The incidences for specific intersectional strata are hidden in this table but we present them in Fig. 2 and in Table 2 and Table A1 (Appendix). The green boxes indicate the actual category. For each category, we show the total number of individuals and the absolute incidence of COPD.

High age		Female gender		Income			Low education		Living alone		Immi-grant		Number (% COPD)	Model 1	Model 2	Model 3
No	Yes	No	Yes	Hi	Me	Lo	No	Yes	No	Yes	No	Yes			OR (95% CI)	OR (95%CI)
■													1180420 (0.10)		Ref.	Ref.
	■												1265081 (0.33)		3.79(2.90–4.91)	3.62 (3.22–4.08)
		■											1228715 (0.20)			Ref.
			■										1216786 (0.24)			1.21 (1.08–1.36)
				■									831992 (0.14)			Ref.
					■								829423 (0.21)			1.52 (1.31–1.76)
						■							784086 (0.32)			2.25 (1.96–2.59)
							■						1070164 (0.11)			Ref.
								■					1375337 (0.30)			1.97 (1.76–2.21)
									■				1665239 (0.16)			Ref.
										■			780262 (0.36)			1.88 (1.69–2.10)
											■		2080162 (0.21)			Ref.
												■	365339 (0.26)			1.15 (1.01–1.29)
Variance between strata (SE)														0.83 (0.14)	0.40 (0.07)	0.04 (0.01)
Intra Class Correlation (95% Credible Interval)														20.0 (15.6–25.6)	10.8 (8.1–14.1)	1.1 (0.6–2.1)
Bayesian diagnostic information criterion (DIC)														661.87	650.21	628.31

Table 2
Total number of individuals, number of cases of Chronic Obstructive Pulmonary Disease (COPD) and predicted incidence in 2011 for people aged 45-65 residing in Sweden on Dec 31st 2010, by intersectional strata. Predictions are based on model 1 multilevel regression analysis with individuals at the first level and intersectional strata at the second level. Main effects and interactive effects are conflated. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45–65 years, education, civil status and country of birth. Intersectional strata are ordered according to predicted incidence of COPD, with increasing incidence in descending rows. For a full table with data for all 96 intersectional strata, see Appendix Table A1.

Age		Gender		Income			Education		Living alone		Immigrant				*Model 1*	
45-54	55-65	Male	Female	High	Medium	Low	High	Low	No	Yes	Yes	No	*Number of individuals*	*Number of cases*	*Incidence*	*95% Credible interval*
The five strata with lowest incidence of Chronic Obstructive Pulmonary Disease in 2011																
✓		✓		✓			✓		✓			✓	50798	9	0.02	(0.01 – 0.04)
✓		✓			✓		✓		✓			✓	72164	19	0.03	(0.02 – 0.04)
✓		✓				✓	✓		✓			✓	54482	16	0.03	(0.02 – 0.05)
✓			✓		✓		✓		✓			✓	74237	26	0.04	(0.03 – 0.05)
✓			✓	✓			✓		✓		✓		6991	1	0.04	(0.01 – 0.09)
The five strata with highest incidence of Chronic Obstructive Pulmonary Disease in 2011																
	✓	✓				✓	✓			✓	✓		2957	19	0.59	(0.36 – 0.90)
	✓	✓				✓		✓		✓		✓	45939	370	0.80	(0.72 – 0.88)
	✓	✓				✓		✓		✓	✓		10450	88	0.82	(0.66 – 1.00)
	✓		✓			✓		✓		✓	✓		12805	113	0.87	(0.72 – 1.05)
	✓		✓			✓		✓		✓		✓	41513	409	0.98	(0.89 – 1.08)

Table 3
Incidence of Chronic Obstructive Pulmonary Disease during 2011 for people aged 45-65 residing in Sweden on Dec 31st 2010, by intersectional strata. Predicted incidences and their 95% CIs based on the total effect (intersectional effects and main effects) and main effects only, in model 3. Interaction effects calculated as total effect minus main effect. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45-65 years, education, living alone and immigration status. In this table only the five strata with the most negative (protective) and the most positive (hazardous) interaction effects are shown. Intersectional strata are ordered according to their interaction effects with the lowest first and increased interaction effects in descending rows. Strata with 95% CIs excluding 0 are bold. For a full table showing data for all 96 intersectional strata, see Table A2 in Appendix and Figs. 3 and 4.

Age		Gender		Income			Education		Living alone		Immigrant		Model 3					
													Total		*Main effects*		*Total - main effects*	
45-54	55-65	Male	Female	High	Medium	Low	High	Low	No	Yes	Yes	No	*Incidence*	*95% CI*	*Incidence*	*95% CI*	*Interaction*	*95% CI*
The five intersectional strata with the most negative (protective) interaction effect																		
	✓		✓			✓		✓		✓	✓		0.92	0.77 – 1.07	1.06	0.92 – 1.23	-0.15	-0.35 – 0.06
	✓		✓		✓			✓		✓	✓		0.59	0.46 – 0.75	0.72	0.61 – 0.84	-0.13	-0.28 – 0.04
	✓		✓			✓		✓	✓		✓		0.45	0.36 – 0.55	0.57	0.49 – 0.65	-0.11	-0.23 – 0.00
	✓		✓			✓	✓		✓		✓		0.23	0.17 – 0.31	0.29	0.25 – 0.34	-0.06	-0.12 – 0.02
	✓	✓		✓				✓		✓		✓	0.29	0.25 – 0.33	0.34	0.29 – 0.40	-0.05	-0.12 – 0.01
The five intersectional strata with the most positive (hazardous) interaction effect																		
✓			✓		✓			✓		✓		✓	0.23	0.18 – 0.28	0.17	0.15 – 0.20	**0.06**	**0.01 – 0.11**
	✓	✓				✓	✓			✓	✓		0.51	0.37 – 0.72	0.45	0.38 – 0.53	0.06	-0.08 – 0.25
	✓	✓			✓			✓	✓		✓		0.39	0.29 – 0.50	0.32	0.27 – 0.37	0.07	-0.02 – 0.18
✓		✓				✓		✓		✓		✓	0.29	0.25 – 0.35	0.21	0.18 – 0.25	**0.08**	**0.03 – 0.13**
✓			✓			✓		✓		✓		✓	0.39	0.33 – 0.45	0.26	0.22 – 0.30	**0.13**	**0.07 – 0.20**

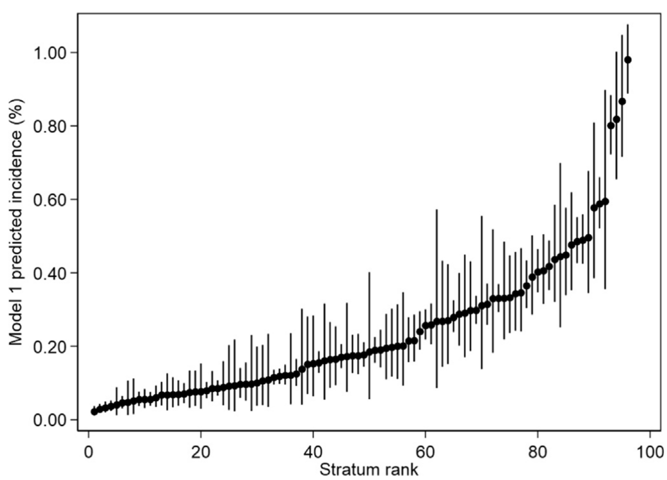

Fig. 2. Predicted incidence of Chronic Obstructive Pulmonary Disease in 2011 for people aged 45–65 residing in Sweden on Dec 31st 2010, by intersectional strata. Predictions are based on model 1 multilevel regression analysis with individuals at the first level and intersectional strata at the second level. Main effects and interactive effects are conflated. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45–65 years, education, civil status and country of birth. Intersectional strata are ordered according to their rank, strata with lowest rank to the left. For identification of the different intersectional strata, see Table 2 and Table A1.

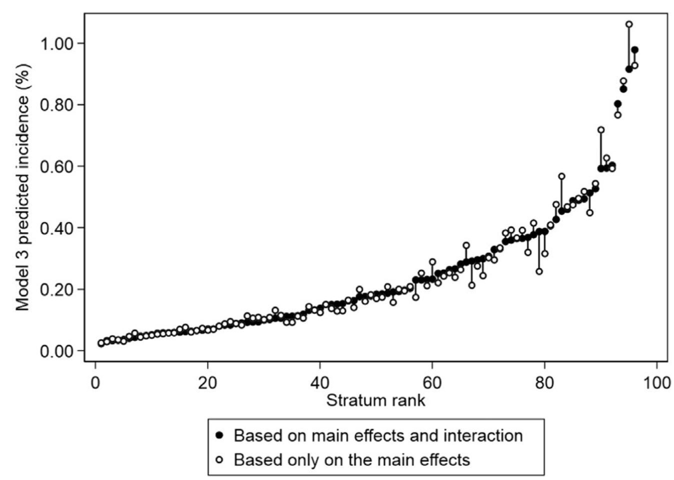

Fig. 3. Incidence of Chronic Obstructive Pulmonary Disease during 2011 for people aged 45–65 residing in Sweden on Dec 31st 2010, by intersectional strata. Point estimates of predicted incidences based on model 3. Black circles indicate the incidence according to predictions based on the total effect (intersectional effects and main effects) while white circles indicate the incidence according to predictions based on main effects only. The differences between black and white circle depict the interaction effects. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45–65 years, education, living alone and immigration status. To identify the different intersectional strata, see Table 3 and Table A2 (Appendix).

The same was true for identifying groups with a lower COPD incidence (e.g., young native males with high income and high education who cohabited). The incidence in the most vulnerable stratum was 49 times higher than the incidence in the most protected stratum. Compared to studies focused on unidimensional demographic and socioeconomic measures, this approach allows for a better understanding of the distribution of COPD incidence in the population. For example, both low income and low education are considered to be socioeconomic predictors of COPD (Gershon et al., 2012). Nevertheless, young men with high education that cohabited with another adult and were born in Sweden always belong to the strata with the lowest predicted incidence regardless of whether their income was high (predicted incidence = 0.02%, 95%CI 0.01–0.04%), medium (predicted incidence = 0.03% 95%CI 0.02–0.04%) or low (predicted incidence = 0.03%, 95%CI: 0.02–0.05%). This indicates that with sufficient protecting factors, exposure to low income is not as hazardous as it is for individuals lacking those protective factors. On the other hand, older men with low income who were cohabiting and had immigrated had a clear COPD risk despite high education (predicted incidence = 0.60 95%CI 0.36–0.90). These results show that a protective factor like high education cannot counterbalance increased COPD-risk caused by additive hazardous effects of other social exposures. Intersectional MAIHDA, thus, provides worthy quantitative information on how societal factors that condition COPD risk intersect and overlap.

Though the ICC of model 3 that isolated interaction effects was poor

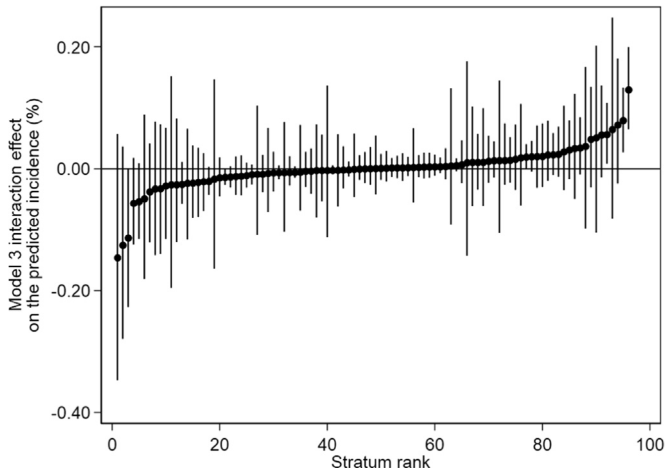

Fig. 4. Intersectional interaction effects on incidence of Chronic Obstructive Pulmonary Disease during 2011 for people aged 45–65 residing in Sweden on Dec 31st 2010, by intersectional strata. Point estimates of the incidences attributable to intersectional interaction and their 95% CIs based on model 3. Interaction effects are calculated as the incidence according to the total effect (intersectional effects and main effects) minus incidence according to main effect only, for each intersectional stratum. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45–65 years, education, living alone and immigration status. Intersectional strata are ordered according to their intersectional interaction effect. To identify the different intersectional strata, see Table 3 and Table A2 (Appendix).

and only three of the 96 strata had interaction effects with 95% CIs excluding 0, which is about what would be expected by chance, the directions of the interactions are interesting. For example, among young women with low education and low income that lived alone, intersectional interaction may explain why natives had higher incidence of COPD than immigrants. A previous study using a fixed effects approach found interactions between gender and race in the USA (Fuller-Thomson, Chisholm & Brennenstuhl, 2016). Also, a study of lung cancer mortality in the USA with an explicit intersectional approach comprising gender, race, income and education found that black men had a higher mortality risk than white men but black women had markedly lower mortality risk than white women (Williams et al., 2012). Intersectional interaction has been shown for obesity in the USA using multilevel analyses (Evans et al., 2017), but not for ischemic heart disease in Sweden applying a traditional logistic regression analyses and measures of DA (Wemrell et al., 2017b). Altogether, this suggests that whether or not intersectional interaction takes place depends on both the context and the studied outcome, which underscores the importance of replicating intersectional findings in different contexts and for distinct health outcomes.

Implications of MAIHDA for social epidemiology of COPD incidence

From a public health perspective, it is less important however whether observed differences between intersectional strata are due to additive or interaction effects. The analysis of ICC, on the other hand, is relevant for public health researchers and policy-makers. The ICC provides analogous information to that delivered by measures of DA, which is a standard measure for evaluating biomarkers and diagnostic tests (Pepe et al., 2004). While measures of DA are used for the evaluation of predictive risk models among COPD-patients (Garcia-Rivero et al., 2016; Sundh & Ekström, 2017), the DA approach is also being applied for questioning the role of traditional risk factors (Merlo et al., 2017), and other categorizations in public health (Merlo & Mulinari, 2015). Socioeconomic and demographic categorizations are cornerstone concepts in (social) epidemiology that provide fundamental information for policy makers and clinicians. However, the relevance of such categorizations must be properly assessed.

While intersectional categories from the "normative" vantage point adopted in much qualitative intersectional research represent social locations whose relevance cannot be tested or refuted statistically (Hancock, 2013), from a public health perspective intersectionality generates empirically testable research questions that can guide quantitative social epidemiological research. More specifically, MAIHDA and the decomposition of the variance to within-group and between-group components is a suitable tool for the evaluation of the relevance of an intersectional categorization in quantitative public health research (Merlo, 2017).

A related and key question for public health is if selective interventions can be justified in specific strata on the basis of knowledge on the size of the difference between strata averages (e.g., differences in incidences between intersectional strata). The answer we propose to this question is influenced by the three perspectives or "complexities" within intersectionality that McCall recognizes (McCall, 2005): the *intercategorical*, the *anticategorical* and the *intracategorical*. According to this author, the *anticategorical approach* is based on the insight that social life is too complex for simple categorization and that unproblematized use of social categories runs the risk of essentialization and perpetuation of existing power structures of which such categorizations form part. Those social categories should be deconstructed since society is too complex to be reduced to simple categories and deconstructing categorizations is a way of deconstructing inequality itself. The *intercategorical approach,* accepts the provisional adoption of categories with the purpose of documenting inequalities between categories. Finally, the *intracategorical approach* tends to "focus on particular social groups at neglected points of intersection…in order to reveal the complexity of lived experiences within such groups" (McCall, 2005) (p.1774). The intracategorical approach is reasonable within a qualitative framework. However, from a quantitative perspective, the intracategorical approach cannot be distinguished from the intercategorical approach but it just suggests the need for a more detailed classification. Consequently, the intercategorical and anticategorical perspectives appear most relevant for addressing the question of whether selective intervention can be justified in specific intersectional strata on the basis of knowledge of the size of the difference between strata averages (Merlo, 2017; Mulinari et al., 2017; Wemrell et al., 2017a).

Specifically we argue, from an anti-categorical point of view, should the ICC be poor, an intervention in specific intersectional strata guided by difference between strata averages should be considered inappropriate since the overlap in individual risk heterogeneity between strata is very high. Even a good ICC of 20.0%, as found in our study, points towards substantial remaining heterogeneity regarding COPD-incidence within intersectional strata. From a public health perspective, the increased incidence of COPD identified for some strata together with a good ICC supports intercategorical intersectionality and the idea of identifying societal factors that condition COPD risk in those specific strata. Besides, from a clinical perspective, a high DA also supports targeted interventions (for instance voluntary spirometry screening) in specific intersectional strata. In this case, the intersectional approach ensures a much higher accuracy than customary unidimensional analyses based on income, education or occupation gradients.

Strengths and weaknesses

Our study is based on a large database that covers the whole population of Sweden and the socioeconomic and demographic information is of high quality (Statistics Sweden, 2012). Noteworthy, the smallest stratum had 1236 individuals which increases the reliability of the stratum specific estimations and render unnecessary the use of shrunken residuals. Also, ICD-codes for COPD in Sweden have been validated and are sufficiently valid for epidemiological studies

(Inghammar, Engstrom, Lofdahl & Egesten, 2012). In this study, we analysed incidence rather than prevalence of COPD. This may generate more conservative results since more individuals were excluded due to prior COPD-diagnosis in strata with high incidence of COPD than in more privileged strata with a low incidence. We chose to study incidence to avoid reverse causality between income and COPD (i.e., existence of COPD leads to low income rather than the opposite).

In intersectionality theory, focus is directed towards power dynamics and social processes that position individuals along interwoven axes of socio-economic differentiation in society. In register studies, these processes (e.g., capitalist exploitation, sexism, racism) are not accessible for direct investigation but are measured through proxies (e.g., individual income, education, sex, country of birth). Whereas this flaw is inherent to intersectional register studies, we have designed our matrix using variables that are as close to the power dynamics of interest as possible. Due to lack of further information about gender, this variable was subject to binary definition as male or female, although this excludes recognition of people of trans- or non-binary gender. We did not have information on sexual orientation, which limits the accuracy of our intersectional stratification since homo- and transphobia are important components in intersectionality research (Collins, 2002) and since some risk factors for COPD are more prevalent among Lesbian-Gay-Bisexual-Transgender individuals (Jannat-Khah, Dill, Reynolds & Joseph, 2017). By using information on country of birth rather than on ethnicity, we avoid endorsing hypotheses of cultural differences, but on the other hand, we fail to assess racism and racialization directly. Similarly, our lack of data on class relations impeded a proper class analysis. Income is a measure of purchasing power that theoretically affects health by determining what material assets are available for an individual (Lynch, Smith, Kaplan & House, 2000). Education is a Weberian-originated variable that corresponds to life-chances (Galobardes, Shaw, Lawlor & Lynch, 2006). Neither of these evaluate the influence of social class as a multidimensional parameter reflecting ownership, skill and authority (Wright, 1997).

As discussed in a previous paper (Axelsson Fisk & Merlo, 2017), smoking is considered a mediator rather than a confounder for socio-economic disparities in respiratory health. Adjustment for smoking would lead to underestimation of differences across intersectional strata. The lack of information on tobacco use can still be considered a limitation of this study, since it would be valuable to discern how much of the differences between intersectional strata observed that are due to tobacco use.

We only had information on COPD-diagnoses retrieved from hospitals, although most COPD-patients visit primary health care. This situation may reduce the absolute incidence values. We cannot exclude, however, that individuals with COPD belonging to socially advantaged strata are well controlled at the primary health care and have less frequent hospital visits, which could underestimate the incidence of COPD among privileged strata. On the other hand, if privileged strata are referred to specialists more readily than patients in disadvantaged strata (Bongers, van der Meer, van den Bos & Mackenbach, 1997), this could counterbalance this effect. In the future, socioeconomic studies should be performed on Swedish databases comprising diagnoses from both hospitals and primary health care.

Since an intersectional life-course approach (Warner & Brown, 2011) was, unfortunately, beyond the scope of our study we wanted to include age-categories in our intersectional matrix. We included only two age categories but evaluated the contribution of age to ICC in model 2. Use of finer age-stratifications would have decreased the number of individuals in the intersectional strata and reduced the interpretability of the results.

Conclusions and recommendations

Although no causal conclusions can be drawn from this observational study, policies that enhance equality between genders, social classes, people from different countries and people living in different family situations are needed to reduce socially determined disparities in COPD incidence. Research has shown that social disparities are best addressed by broad policies that may be beneficial not only for preventing COPD incidence but for decreasing health disparities for many other diseases and for all social strata (Wilkinson & Pickett, 2009). A systematic quality improvement initiative in Denmark eliminated socioeconomic differences in COPD care during four years (Tottenborg, Lange, Thomsen, Nielsen & Johnsen, 2017). In contrast, the privatizations of primary health care that have taken place in Sweden allocate health resources to affluent individuals (Burstrom *et al.* 2017) with lower risk and may therefore exacerbate such disparities.

Intersectional MAIHDA provides a better theoretical and analytical framework for the evaluation of socioeconomic and demographic disparities in respiratory health and health care utilisation than unidimensional analyses of gradients in health. The relevance of intersectionality for COPD risk calls on researchers and policy makers to simultaneously consider combinations of demographic, social and economic dimensions when investigating and targeting inequalities in COPD morbidity.

Ethics

The Regional Ethics Review Board in southern Sweden (# 2012/637) as well as the data safety committees from the National Board of Health and Welfare and from Statistics Sweden approved the construction of the database used in this study.

Acknowledgements

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Appendix

See Appendix Tables A1 and A2.

Table A1
Total number of individuals, number of cases of Chronic Obstructive Pulmonary Disease and predicted incidence in 2011 for people aged 45–65 residing in Sweden on Dec 31st 2010, by intersectional strata. Predictions are based on model 1 multilevel regression analysis with individuals at the first level and intersectional strata at the second level. Main effects and interactive effects are conflated. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45–65 years, education, civil status and country of birth. Intersectional strata are ordered according to predicted incidence of COPD, with increasing incidence in decreasing rows.

Age		Gender		Income			Education		Living alone		Immigrant				*Model 1*	
45-54	55-65	Male	Female	High	Medium	Low	High	Low	No	Yes	Yes	No	*Number of individuals*	*Number of cases*	*Incidence*	*95% Credible interval*
✓		✓		✓			✓		✓			✓	50798	9	0.02	(0.01 – 0.04)
✓		✓			✓		✓		✓			✓	72164	19	0.03	(0.02 – 0.04)
✓		✓				✓	✓		✓			✓	54482	16	0.03	(0.02 – 0.05)
✓			✓		✓		✓		✓			✓	74237	26	0.04	(0.03 – 0.05)
✓			✓	✓			✓		✓		✓		6991	1	0.04	(0.01 – 0.09)
✓			✓	✓			✓		✓			✓	56851	25	0.05	(0.03 – 0.07)
✓		✓		✓				✓		✓	✓		5473	1	0.05	(0.01 – 0.11)
✓		✓			✓		✓			✓		✓	6685	2	0.05	(0.02 – 0.11)
✓		✓		✓			✓			✓		✓	27451	14	0.06	(0.03 – 0.08)
✓		✓			✓			✓	✓			✓	58098	31	0.06	(0.04 – 0.08)
✓			✓			✓	✓		✓			✓	55705	30	0.06	(0.04 – 0.08)
✓		✓		✓				✓	✓			✓	25075	14	0.06	(0.04 – 0.09)
✓			✓	✓			✓			✓		✓	22160	14	0.07	(0.04 – 0.10)
✓			✓		✓			✓	✓		✓		9021	5	0.07	(0.03 – 0.13)
✓		✓				✓	✓		✓		✓		20321	13	0.07	(0.04 – 0.11)
✓			✓			✓	✓			✓		✓	13516	8	0.07	(0.03 – 0.12)
✓			✓	✓				✓	✓			✓	31143	21	0.07	(0.05 – 0.10)
✓		✓			✓		✓		✓		✓		9481	6	0.08	(0.03 – 0.14)
✓		✓			✓			✓	✓		✓		6549	4	0.08	(0.03 – 0.15)
✓			✓		✓		✓		✓		✓		11853	8	0.08	(0.04 – 0.14)
✓		✓		✓				✓		✓		✓	57497	45	0.08	(0.06 – 0.10)
✓		✓				✓		✓	✓			✓	68586	58	0.09	(0.07 – 0.11)
✓			✓			✓	✓		✓		✓		19625	16	0.09	(0.05 – 0.13)
✓		✓				✓	✓			✓		✓	7809	6	0.09	(0.04 – 0.16)
✓			✓	✓				✓	✓		✓		3076	2	0.09	(0.03 – 0.20)
✓		✓		✓				✓	✓		✓		1993	1	0.09	(0.02 – 0.22)
✓			✓	✓				✓		✓		✓	20237	19	0.10	(0.06 – 0.14)
✓			✓		✓		✓			✓		✓	11206	10	0.10	(0.05 – 0.16)
✓			✓		✓		✓			✓	✓		1943	1	0.10	(0.02 – 0.23)
✓		✓		✓			✓		✓		✓		4613	4	0.10	(0.04 – 0.20)
✓			✓		✓			✓		✓	✓		4351	4	0.11	(0.04 – 0.20)
✓		✓		✓			✓			✓	✓		3334	3	0.11	(0.04 – 0.23)
	✓		✓	✓			✓		✓			✓	98120	113	0.12	(0.10 – 0.14)
	✓	✓		✓			✓		✓			✓	101692	120	0.12	(0.10 – 0.14)
✓			✓		✓			✓	✓			✓	62902	76	0.12	(0.10 – 0.15)
✓			✓	✓			✓			✓	✓		2926	3	0.12	(0.04 – 0.24)
✓		✓			✓			✓		✓		✓	32367	40	0.13	(0.09 – 0.17)
✓			✓	✓				✓		✓	✓		2450	3	0.14	(0.04 – 0.30)
✓		✓			✓			✓		✓	✓		4795	7	0.15	(0.07 – 0.28)
✓			✓			✓	✓			✓	✓		4099	6	0.15	(0.06 – 0.28)
✓			✓			✓		✓	✓			✓	71224	111	0.16	(0.13 – 0.19)
	✓	✓		✓			✓			✓	✓		2606	4	0.16	(0.06 – 0.32)
	✓	✓		✓			✓		✓		✓		6786	11	0.16	(0.09 – 0.27)
	✓		✓			✓	✓		✓		✓		9085	15	0.17	(0.09 – 0.25)
	✓	✓			✓		✓		✓			✓	57439	98	0.17	(0.14 – 0.21)
	✓	✓		✓				✓	✓		✓		4071	7	0.17	(0.08 – 0.32)

(continued on next page)

Table A1 (*continued*)

✓		✓				✓		✓	✓		✓		21782	38	0.18	(0.12 – 0.23)
	✓	✓				✓	✓		✓			✓	25095	44	0.18	(0.13 – 0.23)
	✓	✓		✓				✓	✓			✓	59437	105	0.18	(0.15 – 0.21)
✓		✓			✓		✓			✓	✓		1626	3	0.19	(0.06 – 0.40)
	✓		✓		✓		✓		✓			✓	54766	104	0.19	(0.16 – 0.23)
	✓	✓		✓			✓			✓		✓	28371	54	0.19	(0.14 – 0.25)
	✓		✓		✓		✓		✓		✓		8181	16	0.20	(0.11 – 0.29)
	✓		✓	✓			✓		✓		✓		8567	17	0.20	(0.12 – 0.30)
	✓	✓			✓		✓		✓		✓		7825	16	0.20	(0.11 – 0.31)
✓		✓				✓	✓			✓	✓		3886	8	0.20	(0.09 – 0.35)
	✓		✓			✓	✓		✓			✓	21579	47	0.22	(0.16 – 0.28)
✓			✓			✓		✓	✓		✓		22559	49	0.22	(0.16 – 0.29)
	✓		✓	✓			✓			✓		✓	36219	87	0.24	(0.19 – 0.30)
	✓		✓	✓				✓	✓			✓	57118	148	0.26	(0.22 – 0.30)
✓			✓		✓			✓		✓		✓	28024	73	0.26	(0.21 – 0.32)
	✓	✓			✓		✓			✓	✓		1236	4	0.27	(0.09 – 0.57)
	✓		✓	✓			✓			✓	✓		4219	12	0.27	(0.15 – 0.43)
	✓		✓	✓				✓	✓		✓		4986	14	0.27	(0.15 – 0.42)
	✓	✓		✓				✓		✓		✓	54576	153	0.28	(0.24 – 0.33)
	✓	✓				✓	✓		✓		✓		11252	33	0.29	(0.20 – 0.40)
	✓	✓		✓				✓		✓	✓		4864	15	0.29	(0.17 – 0.45)
	✓	✓			✓		✓			✓		✓	6858	21	0.30	(0.19 – 0.43)
	✓	✓			✓			✓	✓			✓	82655	247	0.30	(0.26 – 0.34)
	✓		✓		✓		✓			✓	✓		2049	7	0.31	(0.14 – 0.56)
✓		✓				✓		✓		✓		✓	41080	130	0.32	(0.26 – 0.37)
	✓		✓	✓				✓		✓	✓		4275	15	0.33	(0.18 – 0.52)
	✓	✓				✓	✓			✓		✓	7596	26	0.33	(0.22 – 0.49)
	✓		✓		✓			✓	✓			✓	85879	285	0.33	(0.29 – 0.37)
	✓		✓		✓			✓	✓		✓		11217	38	0.33	(0.24 – 0.45)
✓		✓				✓		✓		✓	✓		11402	40	0.34	(0.24 – 0.46)
✓			✓			✓		✓		✓	✓		10107	36	0.35	(0.24 – 0.47)
	✓		✓	✓				✓		✓		✓	34017	125	0.37	(0.30 – 0.43)
	✓		✓		✓		✓			✓		✓	12088	48	0.39	(0.29 – 0.50)
	✓	✓				✓		✓	✓			✓	43509	177	0.40	(0.35 – 0.47)
	✓		✓			✓		✓	✓		✓		15257	63	0.41	(0.32 – 0.51)
✓			✓			✓		✓		✓		✓	36867	155	0.42	(0.35 – 0.49)
	✓	✓			✓			✓	✓		✓		9411	42	0.44	(0.32 – 0.59)
	✓		✓			✓	✓			✓	✓		3106	15	0.45	(0.25 – 0.70)
	✓	✓				✓		✓	✓		✓		13963	64	0.45	(0.34 – 0.58)
	✓		✓			✓	✓			✓		✓	8710	43	0.48	(0.35 – 0.62)
	✓		✓			✓		✓	✓			✓	48220	236	0.49	(0.43 – 0.55)
	✓	✓			✓			✓		✓		✓	38031	187	0.49	(0.43 – 0.56)
	✓		✓		✓			✓		✓	✓		7166	37	0.50	(0.35 – 0.68)
	✓	✓			✓			✓		✓	✓		4749	29	0.58	(0.39 – 0.81)
	✓		✓		✓			✓		✓		✓	44571	264	0.59	(0.52 – 0.66)
	✓	✓				✓	✓			✓	✓		2957	19	0.59	(0.36 – 0.90)
	✓	✓				✓		✓		✓		✓	45939	370	0.80	(0.72 – 0.88)
	✓	✓				✓		✓		✓	✓		10450	88	0.82	(0.66 – 1.00)
	✓		✓			✓		✓		✓	✓		12805	113	0.87	(0.72 – 1.05)
	✓		✓			✓		✓		✓		✓	41513	409	0.98	(0.89 – 1.08)

Table A2

Incidence of Chronic Obstructive Pulmonary Disease for people aged 45-65 residing in Sweden on Dec 31st 2010, by intersectional strata. Predicted incidences and their 95% CIs based on total effect (intersectional effects and main effects) and main effects only. Interaction effects calculated as total effect minus main effect. Intersectional strata were calculated by categories of age, gender, income based on tertiles in the whole population aged 45-65 years, education, living alone and immigration status. Intersectional strata are ordered according to their interaction effects with the lowest first and increased interaction effects in descending rows. Strata with 95% CIs excluding 0 are bold.

Age		Gender		Income			Education		Living alone		Immigrant		Model 3: Total		Main effects		Total - main effects	
45-54	55-65	Male	Female	High	Medium	Low	High	Low	No	Yes	Yes	No	Incidence	95% CI	Incidence	95% CI	Interaction	95% CI
	✓		✓			✓		✓		✓	✓		0.92	0.77 – 1.07	1.06	0.92 – 1.23	-0.15	-0.35 – 0.06
	✓		✓		✓			✓		✓	✓		0.59	0.46 – 0.75	0.72	0.61 – 0.84	-0.13	-0.28 – 0.04
	✓		✓			✓		✓	✓		✓		0.45	0.36 – 0.55	0.57	0.49 – 0.65	-0.11	-0.23 – 0.00
	✓		✓			✓	✓		✓		✓		0.23	0.17 – 0.31	0.29	0.25 – 0.34	-0.06	-0.12 – 0.02
	✓	✓		✓				✓		✓		✓	0.29	0.25 – 0.33	0.34	0.29 – 0.40	-0.05	-0.12 – 0.01
	✓		✓	✓				✓		✓	✓		0.43	0.31 – 0.58	0.48	0.40 – 0.57	-0.05	-0.18 – 0.09
	✓		✓	✓				✓		✓		✓	0.38	0.32 – 0.44	0.42	0.36 – 0.48	-0.04	-0.12 – 0.04
	✓	✓		✓				✓		✓	✓		0.36	0.26 – 0.48	0.39	0.33 – 0.46	-0.03	-0.14 – 0.08
	✓		✓		✓			✓		✓		✓	0.60	0.53 – 0.67	0.63	0.54 – 0.72	-0.03	-0.14 – 0.07
	✓		✓		✓			✓	✓		✓		0.36	0.28 – 0.45	0.38	0.33 – 0.45	-0.03	-0.12 – 0.07
	✓	✓				✓	✓			✓		✓	0.37	0.27 – 0.47	0.39	0.33 – 0.46	-0.03	-0.12 – 0.08
	✓	✓				✓		✓		✓	✓		0.85	0.71 – 1.01	0.88	0.76 – 1.02	-0.03	-0.20 – 0.15
✓			✓			✓	✓			✓		✓	0.11	0.07 – 0.15	0.13	0.11 – 0.16	-0.03	-0.06 – 0.01
	✓	✓			✓			✓		✓		✓	0.49	0.43 – 0.56	0.52	0.45 – 0.60	-0.02	-0.12 – 0.07
✓			✓		✓			✓		✓	✓		0.18	0.12 – 0.24	0.20	0.17 – 0.24	-0.02	-0.08 – 0.04
	✓		✓			✓	✓		✓			✓	0.23	0.18 – 0.29	0.25	0.22 – 0.29	-0.02	-0.08 – 0.03
✓		✓				✓		✓	✓			✓	0.09	0.07 – 0.11	0.11	0.10 – 0.13	-0.02	-0.04 – 0.00
	✓	✓				✓	✓		✓			✓	0.19	0.15 – 0.23	0.21	0.18 – 0.24	-0.02	-0.07 – 0.03
	✓		✓			✓	✓			✓	✓		0.53	0.38 – 0.71	0.54	0.46 – 0.64	-0.02	-0.16 – 0.15
✓		✓		✓				✓		✓	✓		0.10	0.06 – 0.13	0.11	0.09 – 0.13	-0.02	-0.05 – 0.02
✓		✓				✓	✓		✓			✓	0.04	0.03 – 0.06	0.06	0.05 – 0.07	-0.01	-0.03 – 0.00
✓		✓			✓			✓	✓			✓	0.06	0.05 – 0.08	0.08	0.06 – 0.09	-0.01	-0.03 – 0.00
✓			✓		✓			✓	✓		✓		0.09	0.06 – 0.13	0.11	0.09 – 0.13	-0.01	-0.04 – 0.02
✓		✓			✓			✓		✓		✓	0.13	0.10 – 0.17	0.14	0.12 – 0.17	-0.01	-0.04 – 0.02
✓		✓		✓				✓		✓		✓	0.08	0.07 – 0.10	0.10	0.08 – 0.11	-0.01	-0.03 – 0.01
✓			✓	✓				✓		✓		✓	0.11	0.08 – 0.14	0.12	0.10 – 0.14	-0.01	-0.04 – 0.02
✓			✓			✓	✓		✓			✓	0.06	0.05 – 0.08	0.07	0.06 – 0.08	-0.01	-0.03 – 0.01
	✓	✓				✓		✓	✓		✓		0.46	0.37 – 0.56	0.47	0.40 – 0.54	-0.01	-0.11 – 0.10
✓		✓				✓	✓			✓		✓	0.10	0.07 – 0.14	0.11	0.09 – 0.13	-0.01	-0.04 – 0.03
	✓	✓		✓			✓			✓	✓		0.19	0.13 – 0.28	0.20	0.17 – 0.24	-0.01	-0.07 – 0.07
✓		✓			✓		✓		✓			✓	0.03	0.02 – 0.04	0.04	0.03 – 0.05	-0.01	-0.02 – 0.00
✓		✓			✓		✓			✓		✓	0.07	0.05 – 0.10	0.07	0.06 – 0.09	-0.01	-0.03 – 0.02
✓			✓		✓		✓		✓			✓	0.04	0.03 – 0.05	0.05	0.04 – 0.06	-0.01	-0.02 – 0.01
	✓	✓		✓				✓	✓		✓		0.20	0.14 – 0.28	0.21	0.17 – 0.24	-0.01	-0.07 – 0.07
	✓		✓			✓		✓	✓			✓	0.49	0.43 – 0.55	0.50	0.43 – 0.57	-0.01	-0.10 – 0.08
✓		✓			✓			✓	✓		✓		0.08	0.06 – 0.12	0.09	0.07 – 0.10	0.00	-0.03 – 0.03
	✓	✓		✓				✓	✓			✓	0.18	0.15 – 0.21	0.18	0.16 – 0.21	0.00	-0.04 – 0.03
✓		✓			✓			✓		✓	✓		0.16	0.11 – 0.22	0.17	0.14 – 0.20	0.00	-0.05 – 0.06
	✓	✓				✓		✓	✓			✓	0.41	0.36 – 0.46	0.41	0.35 – 0.47	0.00	-0.08 – 0.07
	✓		✓		✓		✓			✓	✓		0.37	0.25 – 0.52	0.37	0.31 – 0.44	0.00	-0.11 – 0.14
✓		✓		✓			✓		✓			✓	0.02	0.02 – 0.03	0.03	0.02 – 0.03	0.00	-0.01 – 0.01
✓			✓	✓			✓		✓		✓		0.03	0.02 – 0.05	0.04	0.03 – 0.04	0.00	-0.01 – 0.01
✓			✓		✓		✓			✓	✓		0.10	0.07 – 0.15	0.10	0.08 – 0.12	0.00	-0.03 – 0.04
	✓		✓		✓			✓	✓			✓	0.33	0.29 – 0.37	0.34	0.29 – 0.39	0.00	-0.06 – 0.06
✓			✓			✓	✓			✓	✓		0.15	0.10 – 0.21	0.15	0.13 – 0.18	0.00	-0.05 – 0.06
✓		✓				✓	✓		✓		✓		0.07	0.05 – 0.09	0.07	0.06 – 0.08	0.00	-0.02 – 0.02
✓			✓		✓		✓			✓		✓	0.09	0.06 – 0.13	0.09	0.07 – 0.11	0.00	-0.03 – 0.04
✓			✓			✓	✓		✓		✓		0.08	0.06 – 0.11	0.08	0.07 – 0.09	0.00	-0.02 – 0.03
✓		✓		✓				✓	✓		✓		0.06	0.04 – 0.09	0.06	0.05 – 0.07	0.00	-0.02 – 0.02
✓			✓	✓				✓	✓		✓		0.07	0.05 – 0.10	0.07	0.06 – 0.09	0.00	-0.02 – 0.03
✓			✓	✓				✓		✓	✓		0.13	0.09 – 0.19	0.13	0.11 – 0.16	0.00	-0.04 – 0.05
✓		✓		✓			✓			✓		✓	0.05	0.04 – 0.07	0.05	0.04 – 0.06	0.00	-0.01 – 0.02
✓		✓		✓				✓	✓			✓	0.05	0.04 – 0.07	0.05	0.04 – 0.06	0.00	-0.01 – 0.02
✓			✓	✓			✓			✓		✓	0.06	0.04 – 0.08	0.06	0.05 – 0.07	0.00	-0.02 – 0.02

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Table A2 (*continued*)

	✓		✓	✓			✓		✓			✓	0.12	0.10 – 0.14	0.11	0.10 – 0.13	0.00	-0.02 – 0.03
	✓		✓		✓		✓		✓		✓		0.20	0.14 – 0.26	0.20	0.17 – 0.23	0.00	-0.06 – 0.07
✓		✓		✓			✓		✓		✓		0.03	0.02 – 0.05	0.03	0.02 – 0.04	0.00	-0.01 – 0.02
✓		✓		✓			✓			✓	✓		0.06	0.04 – 0.09	0.06	0.05 – 0.07	0.00	-0.02 – 0.03
✓		✓			✓		✓		✓		✓		0.05	0.03 – 0.07	0.05	0.04 – 0.05	0.00	-0.01 – 0.02
✓			✓	✓				✓	✓			✓	0.06	0.05 – 0.09	0.06	0.05 – 0.07	0.00	-0.01 – 0.02
✓			✓		✓		✓		✓		✓		0.06	0.04 – 0.08	0.05	0.05 – 0.07	0.00	-0.02 – 0.03
✓			✓	✓			✓			✓	✓		0.07	0.05 – 0.10	0.07	0.06 – 0.08	0.00	-0.02 – 0.03
✓			✓	✓			✓		✓			✓	0.04	0.03 – 0.05	0.03	0.03 – 0.04	0.01	-0.00 – 0.02
	✓	✓			✓		✓			✓	✓		0.31	0.21 – 0.44	0.30	0.25 – 0.36	0.01	-0.09 – 0.13
✓		✓			✓		✓			✓	✓		0.09	0.06 – 0.14	0.08	0.07 – 0.10	0.01	-0.02 – 0.05
	✓	✓			✓			✓		✓	✓		0.60	0.46 – 0.77	0.59	0.50 – 0.70	0.01	-0.14 – 0.18
	✓		✓	✓				✓	✓		✓		0.26	0.19 – 0.36	0.25	0.21 – 0.30	0.01	-0.06 – 0.10
	✓	✓		✓			✓			✓		✓	0.19	0.15 – 0.23	0.18	0.15 – 0.20	0.01	-0.03 – 0.06
	✓		✓	✓			✓			✓	✓		0.25	0.18 – 0.35	0.24	0.20 – 0.29	0.01	-0.06 – 0.10
	✓	✓		✓			✓		✓		✓		0.12	0.08 – 0.17	0.11	0.09 – 0.13	0.01	-0.02 – 0.05
✓			✓			✓		✓	✓			✓	0.15	0.13 – 0.18	0.14	0.12 – 0.16	0.01	-0.02 – 0.05
	✓		✓			✓	✓			✓		✓	0.49	0.38 – 0.62	0.48	0.40 – 0.55	0.01	-0.11 – 0.14
✓		✓				✓	✓			✓	✓		0.14	0.09 – 0.20	0.13	0.10 – 0.15	0.01	-0.03 – 0.07
	✓		✓		✓		✓		✓			✓	0.19	0.15 – 0.22	0.17	0.15 – 0.20	0.01	-0.02 – 0.05
	✓	✓			✓		✓		✓		✓		0.18	0.13 – 0.24	0.16	0.14 – 0.19	0.02	-0.04 – 0.07
	✓	✓			✓		✓			✓		✓	0.28	0.20 – 0.37	0.27	0.22 – 0.31	0.02	-0.06 – 0.11
	✓	✓		✓			✓		✓			✓	0.11	0.09 – 0.13	0.09	0.08 – 0.11	0.02	0.00 – 0.04
✓			✓		✓			✓	✓			✓	0.11	0.09 – 0.14	0.09	0.08 – 0.11	0.02	-0.01 – 0.05
	✓	✓			✓			✓	✓			✓	0.30	0.26 – 0.33	0.28	0.24 – 0.32	0.02	-0.03 – 0.07
	✓		✓	✓			✓			✓		✓	0.23	0.19 – 0.28	0.21	0.18 – 0.25	0.02	-0.03 – 0.07
	✓	✓			✓		✓		✓			✓	0.16	0.14 – 0.20	0.14	0.12 – 0.16	0.02	-0.01 – 0.06
	✓		✓	✓			✓		✓		✓		0.15	0.11 – 0.21	0.13	0.11 – 0.16	0.02	-0.02 – 0.08
✓		✓				✓		✓	✓		✓		0.15	0.12 – 0.20	0.13	0.11 – 0.15	0.02	-0.01 – 0.07
	✓	✓				✓	✓		✓		✓		0.27	0.20 – 0.35	0.24	0.20 – 0.28	0.03	-0.04 – 0.10
	✓		✓	✓				✓	✓			✓	0.25	0.22 – 0.29	0.22	0.19 – 0.26	0.03	-0.02 – 0.08
✓			✓			✓		✓		✓	✓		0.33	0.25 – 0.42	0.30	0.25 – 0.35	0.03	-0.05 – 0.12
✓			✓			✓		✓	✓		✓		0.19	0.15 – 0.24	0.16	0.13 – 0.18	0.03	-0.01 – 0.08
	✓	✓				✓		✓		✓		✓	0.80	0.72 – 0.89	0.77	0.66 – 0.88	0.04	-0.10 – 0.17
	✓		✓		✓		✓			✓		✓	0.37	0.29 – 0.46	0.32	0.27 – 0.37	0.05	-0.03 – 0.13
	✓		✓			✓		✓		✓		✓	0.98	0.89 – 1.07	0.93	0.80 – 1.07	0.05	-0.11 – 0.20
✓		✓				✓		✓		✓	✓		0.30	0.23 – 0.38	0.24	0.21 – 0.29	0.06	-0.01 – 0.14
✓			✓		✓			✓		✓		✓	0.23	0.18 – 0.28	0.17	0.15 – 0.20	**0.06**	**0.01 – 0.11**
	✓	✓				✓	✓			✓	✓		0.51	0.37 – 0.72	0.45	0.38 – 0.53	0.06	-0.08 – 0.25
	✓	✓			✓			✓	✓		✓		0.39	0.29 – 0.50	0.32	0.27 – 0.37	0.07	-0.02 – 0.18
✓		✓				✓		✓		✓		✓	0.29	0.25 – 0.35	0.21	0.18 – 0.25	**0.08**	**0.03 – 0.13**
✓			✓			✓		✓		✓		✓	0.39	0.33 – 0.45	0.26	0.22 – 0.30	**0.13**	**0.07 – 0.20**

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ssmph.2018.03.005.

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